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PETROCHEMICALS DEPARTMENT
POTOMAC RIVER DEVELOPMENT LABORATORY
E. I. du PONT de NEMOURS & COMPANY
MARTINSBURG, WV 25401

STUDY OF EXPLOSIVE STIMULATION IN DEVONIAN SHALE GAS 'WELLS

Final Report

Contract No.: DE-AC-21-79MC-11843
Principal Investigators: F. A. Loving, Research Associate:
W. J. Simmons, Division Staff Engineer
Report Written By: F. A. Loving
Period Covered: June 17 to September 31, 1980

ABSTRACT

A comparison of explosive treatments in eight Devonian shale wells in Union District, Putnam County, WV is presented. Intervals of about 600 ft were shot with (1) 5 inch diameter gelatin dynamite (6000 lb in 6-1/4 inch hole), (2) EL836 aluminized water gel explosive (12,900 lb in 6-1/4 inch hole) and (3) EL836 in an underreamed hole (37,500 lb in a 12 inch hole). Final open flow data after treatment indicate substantially larger gas flows from the heavier charge-per-foot treatments.

INTRODUCTION

In accordance with contractual agreements with the U. S. Department of Energy (DOE)' and with Cabot Oil & Gas Corporation (formerly Appalachian Exploration & Development Inc.) , a program to study explosives treatment of Devonian shale gas wells in Union District, Putnam-County, WV was begun. Of the thirteen wells in the study, five were to be treated conventionally with 600 ft. x 5 inch columns of 80% Gelatin Dynamite, five with about 600 ft. x 6-1/4 in. columns of EL836 (a Du Pont proprietary water gel explosive) and three with about 600 ft. x 12 in. charges of EL836 in underreamed holes.

SUMMARY AND CONCLUSIONS

Of the planned shots, three of the five 600 ft. dynamite shots were completed and only one of the three underreamed shots was made due to State ordered shutdown of drilling before October 1, 1980 to allow road repairs in the area.

Despite the reduced sample size, substantial improvement in final open 'flow tests was indicated from heavier charge weights per foot of borehole. (Table II).

Good loading of EL836 water gel explosive was achieved. After correction of early mechanical problems loading rates reached 2,000 lb/hr at borehole densities essentially equal to the powder density of 1.50 g/cc (20 lb/ft in 6-1/2 inch diameter, 70 lb/ft in 12 inch diameter holes.)

A large EL836 shot (37,500 lb) blew the stemming and ignited. In anticipation of this possibility the drilling rig had been moved and damage was limited to the drill table and immediate vicinity. The fire was extinguished after about 15 minutes required for closing the blowout preventer.

DETAILS

The Wells

Well locations in this study are plotted in Figure 1. The original sites chosen for dynamite and EL836 treatment were altered to accommodate the drill schedule and to make use of those sites having space for additional air capacity for under-reaming. An attempt was made to avoid concentration of a given type of treatment in one portion of the study area.

Data on the wells loaded by Du Pont are shown in Table I.

Well A-26 was underreamed with an air tool designed by Tristate Tool Co., Cerritos, CA. Air pressure at the Kelly was increased from the normal 250 psi to 550-560 psi with two supplemental compressors and two pressure boosters to facilitate tool opening and cleanout in the 12 inch hole.

Even with extra air, about five hours were required to open the underreaming tool to the locked (12 inch dia) position, and removal of cuttings was slow. Extra "blowing time" about equal to drilling time was required to keep the hole clear of cuttings. After 48 hours of drilling the underreaming tool failed with two cutters lost in the hole. Slightly more than 500 ft. of the desired 600 ft. of enlarged hole was achieved, A good smooth hole was indicated by caliper tapering uniformly from 12-1/2 inch diameter at the top to 11-1/2 diameter at the bottom.

The tool failure was caused by erosion of the internal surfaces of the cutter bars from the blast of air and cuttings from internal air passages. This erosion destroyed the line carrying cooling air to the three cutters resulting in their failure, Tristate has made further design modifications to alleviate this problem.

Well A-26 was successfully loaded and fired with 37,500 lbs of EL836 distributed in 512 ft. of underreamed hole and extending an additional 49 ft. upward into the 6-1/4 in. hole.

The Explosive

EL836, a proprietary Du Pont product, is a highly aluminized water gel explosive containing conventional oxidizing salts with monomethylamine nitrate solution as a sensitizer. It is about ten times less sensitive to initiation by shock, friction or impact than 80% gelatin dynamite gas well explosive containing nitroglycerine. Some computer calculated detonation and isentropic expansion parameters for these two explosives are as follows:

	EL836		80% Gelatin Dynamite	
	Detonation (CJ) Condition	Expanded to- 1 atm.	Detonation (CJ) Condition	Expanded to 1 atm.
Temperature °K	4660	1130	4400	600
Pressure Kbar	115	0.001	93	0.001
Heat of Explosive Kcal/Kgm (Q)	1815		1210	
Expansion Work Kcal/Kgm		1460		1180

If one assumes that useful exoansion which fractures deep rock cannot extend below lithostatic pressure, then a figure of merit for explosives might be the volume of the detonation products expanded to lithostatic pressure. Since the expansion occurs in a very short time, heat transfer may be neglected and the process may be considered isentropic. Isentroozes comparing EL836 with a conventional dynamite shot in a 6-1/4 inch hole are shown in Figure 2 where EL836 at a density of 1.5 g/cc fills the hole wall-to-wall (20 lb/ft) and 5 inch diameter (nominal) 80% gelatin dynamite has a loading density of about 0.81 g/cc (10 lb/ft). If lithostatic pressure for Devonian shale at 5,000 ft. depth is about 0.3 Kbar, it will be seen that EL836 has twice the expanded volume of the dynamite load.

Significant differences are also found in the calculated composition of gaseous products of detonation of El836 and 80% gelatin dynamite. The principal gaseous products following isentropic expansion to 1 atm. pressure are calculated to be:

	EL836 (mols/100 g.)	80% Gelatin Dynamite (mols/100g)
CO	0.28	0.50
CO2	0.03	0.93
H_2	1.47	0.21
H_2O	a.55	1.17
N2	0.61	0.54
Total mols gas	2.94	3.35

The high hydrogen content of EL836 products together with the high expanded temperature noted above makes ignition of the gases more likely following an EL836 shot, particularly if the stemming does not hold until the gases have cooled. Such an event did indeed occur in well A-26 as described below.

Pyrite (FeS2) present in shale may react at high temperature in the presence of detonation products to produce the toxic species H_2S and $Fe(CO)_5$. Gas samples from all of the wells taken after cleanout were analyzed by infrared spectrometer: No $Fe(CO)_5$ was detected. A small quantity of CO was detected in one sample. No odor of H_2S was present at the time samples were taken although the drillers reported that more H_2S odor was noted during cleanout of EL836 shots than is normally found with dynamite.

Loading and Firing

The EL836 was packaged in 4 inch diameter, 25 inch long, 12-1/2 lb limp polyethylene sausage-like cartridges. Sixteen cartridges were loaded into a 27 ft. long x 4-1/4 inch I.D. aluminum loading capsule and lowered with a high speed winch to the bottom of the hole where a release mechanism allowed the cartridges to fall out through the open capsule bottom. A slitting knife mounted in the bottom of the capsule was used in wells A-45 and B-15 to improve the loading density in 6-1/4 inch holes (See Table I). A typical loading cycle required 5-6 minutes per trip (200 lb EL836).

Loading was slowed appreciably in wells A-24 and A-45 by the presence of a substantial amount of water which was apparently entering the wells from surface water via leaks at the collar.

Firing was accomplished with Zero Hour time bombs purchased from Zero Hour Co., Tulsa, Oklahoma. Two duplex bombs were inserted near the top of each charge. Priming charges fabricated from 1.7 lb. Du Pont "Detaflex" extruded plastic explosive were used in each bomb.

Loading and firing notes on each of the wells (Table I) are as follows:

McClean A-31

This was the first well loaded with the high speed winch truck. The principal loading problem arose from vertical accelerations in the loaded capsule during speed transitions in the two-speed Stafa hydraulic motor driving the winch. These accelerations packed cartridges in the capsule on several occasions preventing their unloading at the bottom of the hole. The loaded capsule then had to be removed from the hole and inverted for cleanout. On one occasion the vertical accelleration caused a bounce of the capsule which unloaded before bottom was reached. Cartridges jammed in the hole causing a three hour delay to clear the jam and unsnarlcable on the winch. Adjustments to the hydraulic system eliminated this problem in subsequent loadings.

The time bombs were set at 3 hours to allow time for completion of loading and stemming with about 5-6 tons (~450 ft) of river gravel and two clay plugs near the bottom. The shot fired 1 minute 50 seconds early. Following the shot the stemming held although there was venting of gas and rumbling of stemminq for about 45 minutes. The odor of H_2S was noticeable several hundred feet from the well during this period in a dead calm atmosphere.

McClean A-24

The hydraulic adjustments and improved winch technique resulted in a substantial improvement in loading time in this well. A loading capsule was lost in this well when the lowering cable parted due to an inadvertent overhoist bringing the capsule into contact with the pulley. No adverse effect on shooting or cleanout was noted. The aluminum capsule would doubtless be consumed in the shot.

The time bombs, again set for 3 hours, initiated this hole six seconds early. This precision is fortuitous since clock settings can only be made to about + 1/2 minute.

The stemming held. There was intermittent ven-ting of gas with no audible movement of stemming. No H_2S odor was noted after shot prior to cleanout.

McClean No. 26

This shot comprised 37,500 lb. of EL836 loaded through a 6-1/4 inch dia. hole into an underreamed section calipered at 11-1/2 to 12-1/2 inch diameter. Problems encountered included:

O Underreaming

Tool opening required.4 hours. In spite of extra air provided, as much "blowing time" as drilling time was required to remove cuttings during drilling. (Air volume is principally limited by pressure drop in the annular space available between the drill pipe joints and the 6-1/4 inch hole and is relatively independent of the-available surface pressure of about 550 psi).

After about 48 hours the underreaming tool failed when two cutters were lost in the hole. The failure was due to erosion of the cutter bars by a high velocity air stream from internal vents together with blown cuttings. Slightly more than 500 ft. of the desired 600 ft. of underream was achieved. The final load was 98 ft. off the well bottom. The 12 inch dia. load was 506 ft. long extending an additional 49 ft. up into the 6-1/4 inch hole.

Tristate Tool has rebuilt the underreamer with hardened surfaces in eroded areas, redirected air ports and improved cutting teeth to reduce opening time.

O Loading

Fatigue cracks and weld failures occurred in all five loadingcapsules during the three days required to load the underreamed hole. Emergency repairs at a Charleston machine shop were required to complete the loading. Reconstruction of the capsules was completed to strengthen the weak points before the next well was loaded.

O <u>Shooting</u>

The clocks, set for 5 hrs. to permit backing off the rig, initiated the charge 4 minutes early. About ten minutes after the shot the ten tons of stemming (about 600 ft) was ejected violently, rising to heights of 300 ft. or so. After blowing for another 10 minutes the gases ignited. The fire lasted 10-15 minutes, the time required to close the blowout preventer with a hand operated hydraulic pump. During this period five 30-lb. dry powder extinquishers were emptied on the fire with no effect.

In anticipation of a possible ignition, the drill had been backed off the hole so that damage was confined to the rotary table, the top of the kelly and blistered paint on adjacent structures.

The lower connections to the blowout preventer were leaking badly after the fire. About 1,000 psi pressure remained in the well. These fumes seriouslv interferred with the connection of a two inch vent line which was installed below the blowout preventer to flare down the pressure. H_2S odor was strong and CO was doubtless present. This problem will be avoided in the future by having this line in place prior to shooting.

After flare down, the well was cleaned out with difficulty to 300 ft. into the underreamed section and closed for pressure buildup prior to final open flow tests.

<u>McClean A-45</u>

Loading of this well was somewhat slowed by the presence of surface water leaking into the well through piping joints at the top. However, only one capsule had to be removed from the well for cleaning jammed cartridges. The reinforced capsules showed no sign of fatigue failure.

A slitting knife was used for most of this load resulting in a much improved loading density. The knife was removed near the end of loading so that the borehole rise of powder would reach a show of gas at 3,874 ft.

Initiation occurred 10 minutes 32 seconds early. The stemming held and some venting of gas was observed. No. H_2S odor was detected.

<u>Putnam B-15</u>

The best loading rate of the series about 2,000 lb/hr was achieved without incident.

Initiation was 2 minutes 6 seconds early. The stemming held and no venting was observed prior to cleanout. Al though the normal 6 tons of stemming had been ordered, the dimensions of the pile suggested that somewhat more, perhaps 8 tons or about 650 ft. may have been used.

Dynamite Wells McClean A-32, A-43 & A-52)

These wells were loaded by the King Torpedo Co. with 5 in. dia. x 10 ft. x 100 lb. rigid cartridges of 80% Gelatin Dynamite.

Seismic Effects

Three component seismograph records were obtained near well A-31 (12,000 lb. EL836) and well A-26 (37,500 lb. EL836) by Philip R. Burger & Associates. Bradfordwoods, PA. Their reports and analysis are attached as Appendices A&B.

The maximum peak particle velocities and dominant frequencies were:

	Max Particle Velocity	Dominant Frequency
Well A-31 (12,000 lb)	0.05	32
Well A-26 (37,500 lb)	0.28	40

These values are far below damage levels for structures. Several states have set 2.0 in/sec as a maximum allowable level near surface blasting. The large shot might be sensed by occupants of a structure out to a few miles however.

Performance

Initial open flows for all wells reported here were very low. (All below 1,000 cfd except Putnam B-15 which measured 1,600 cfd). Final open flows shown in Table II were measured with an orifice meter following pressure buildup and 4 hour blow down through a 2 inch vent. A substantial improvement is indicated for the more heavily loaded wells.

Based on limited prior field data, an estimate of increased productivity had been proposed for equal column lengths of dynamite vs EL836. The estimate was

$$\frac{P_1}{P_2} = \left(\frac{E_1}{E_2}\right)^{1/2}$$

where Pl and P2 are gas production corresponding to El and E_2, respective explosion energies per unit borehole volume. The energy ratio for dynamite vs EL836 in equal column heights is then

$$\frac{E_1}{E_2} = \frac{\rho_1 \; Q_1}{\rho_2 \; Q_2}$$

where ρ is the loading density in lbs. loaded/ft. of hole and Q is the heat of explosion (see pg. 4)

The predicted improvement vs observed ratios of mean final open flows (Table II) are

	Improvement Ratio	
	Predicted	Observed
Straight 6-1/2" hole (Dynamite 10 lb/ft vs (EL836 20 lb/ft	1.73	1.57
Underreamed hole (Dynamite 10 lb/ft vs (EL836 70 lb/ft	3.24	3.43

While the precision of the observed means is limited by the small number of observations to date, increased explosives energy per foot of borehole seems to provide a clear and perhaps predictable improvement.

Future Work

In accordance with the contractual agreements Du Pont will obtain from AED and furnish to DOE production data from the wells reported herein for a period of 3 years.

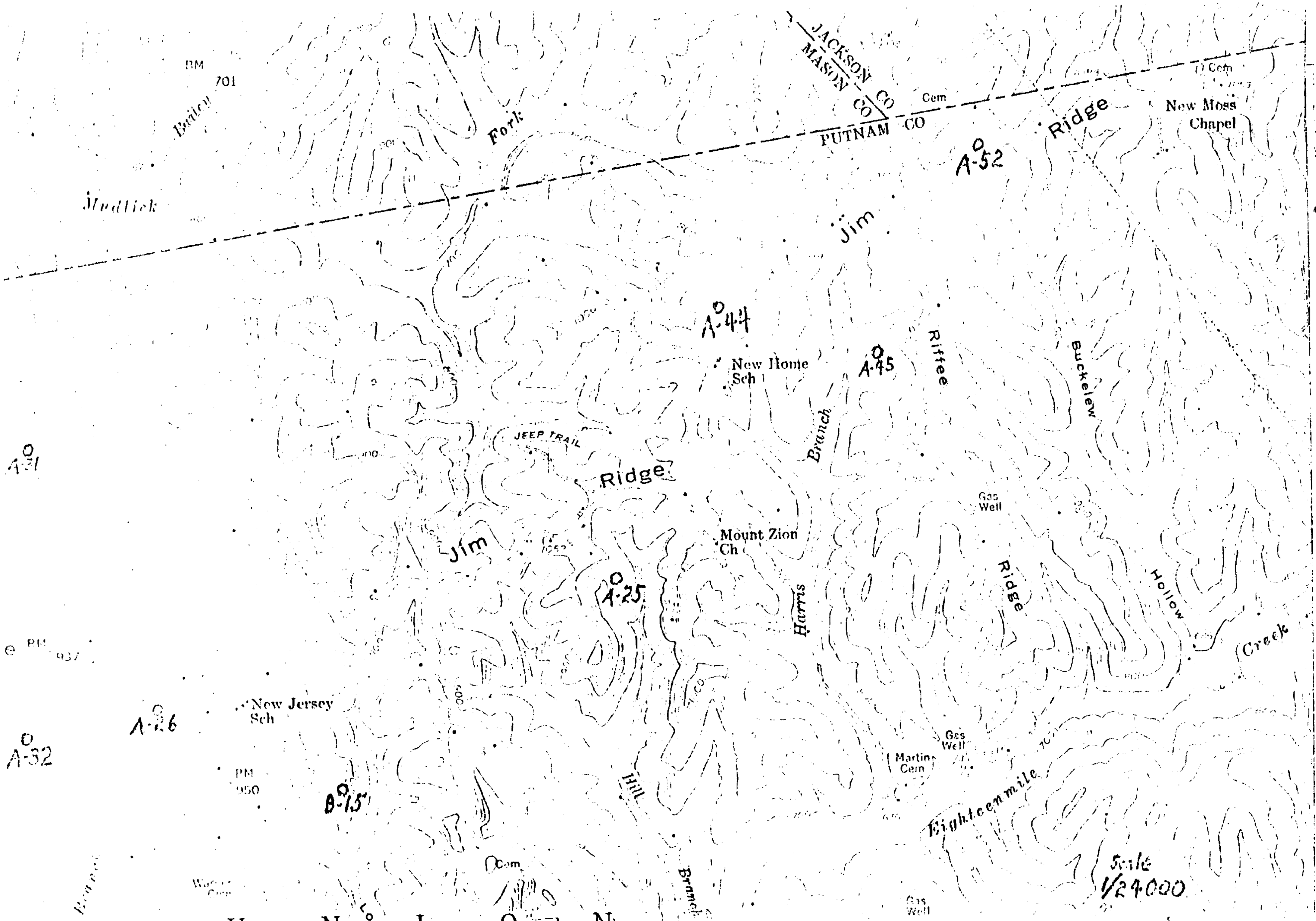


FIGURE 1
ELMWOOD QUADRANGLE
WEST VIRGINIA
7.5 MINUTE SERIES (TOPOGRAPHIC)
NE/4 WINFIELD 15' QUADRANGLE

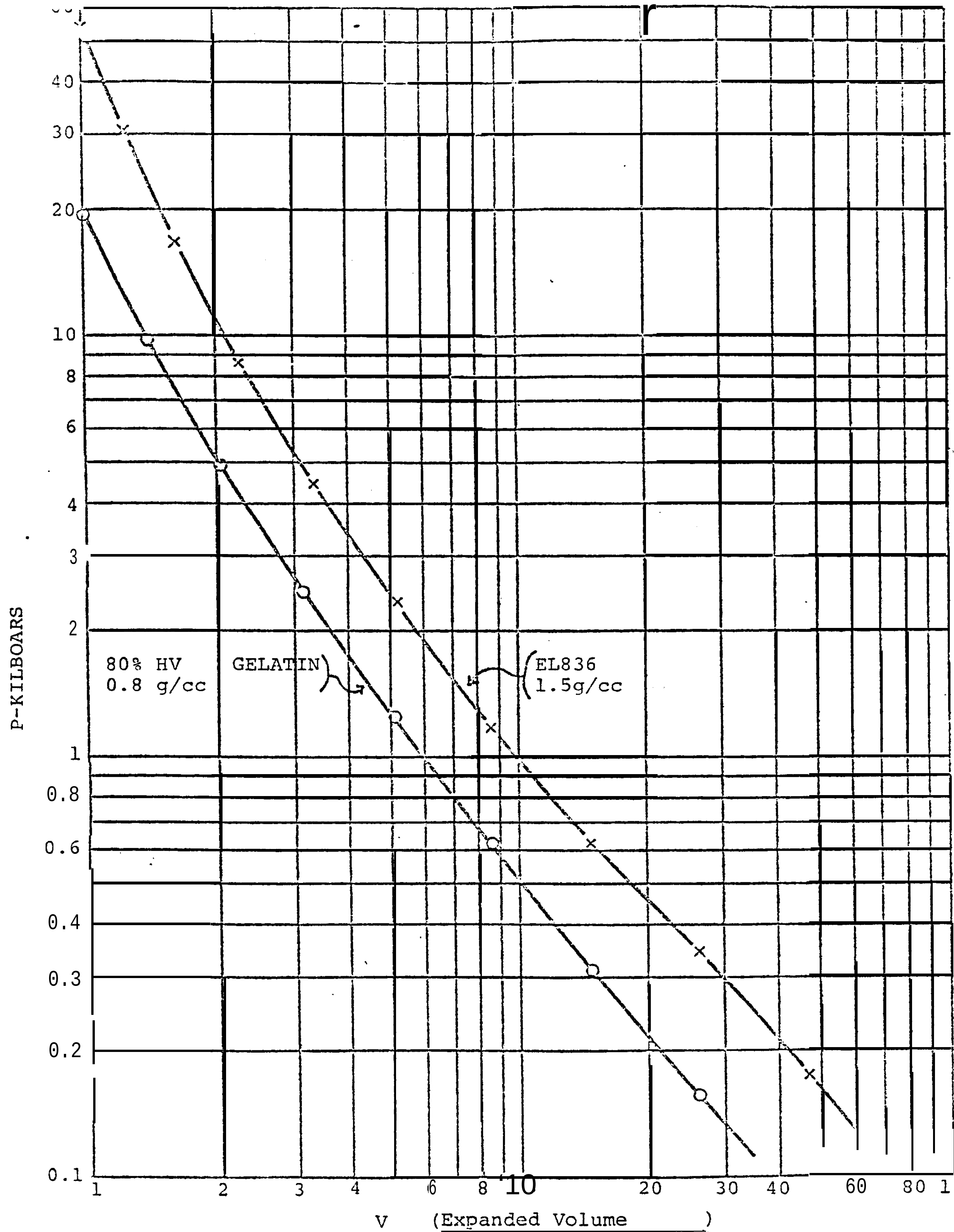

P-KILBOARS
80% HV
0.8 g/cc
GELATIN
EL836
1.5g/cc
40
30
20
10
8
6
4
3
2
1
0.8
0.6
0.4
0.3
0.2
0.1
1
2
3
4
6
8
10
20
30
40
60
80
V (Expanded Volume)
V_o (Volume of Hole Loaded)
FIGURE 2

TABLE I
SUMMARY OF DATA ON WELLS SHOT WITH
EL836 WATER GEL EXPLOSIVE
(open hole diameter 6-1/4 inches)

Well Number	Depth Ft	Casing Depth Ft	Underream Top Ft	Underream Bottom Ft	EL836 lbs	Top of Charge Ft	Loading g/cc	Density lb/ft	Loading Time hrs	Date Fired (EDT)	Time Fired (EDT)	Initial Open Flow (MCFD)	[illegible]
[illegible] A-31	4503	2775	None	None	12,000	3862	1.44	18.7	12-1/2	6/17/80	11:58:10P	< 1	
[illegible] A-24	4594	2779	None	None	12,000	3868	1.26	16.1	9-1/2	7/2/80	9:14:54	< 1	Hole wet
[illegible] A-25	4538	2755	None	None	12,000	3866	1.35	17.9	8	7/24/80	8:29:35	< 1	
[illegible] A-26	4533	2727	3929	4435	37,500	3880	1.50*	73*	23	8/9/80	4:55:59P	< 1	
[illegible] A-45	4488	2748	None	None	12,000	3855	1.43	19	8	8/24/80	6:49:28P	< 1	Hole wet, csgs. slit except for last 2500 lbs.
[illegible] 1-15	4458	2736	None	None	12,000	3853	1.50	20.0	6	9/6/80	5:27:54	1.0	Csgs. slit

*Underreamed section (12" dia.)

TABLE.11
FINAL OPEN FLOW DYNAMITE VS EL836
MCFD AFTER 4HRS. VENTING THRU 2" VENT

Dynamite ~600' Column - 6-1/4" Dia			EL836 ~600' Column - 6-1/4" Dia			EL836 ~500' Column - 1¾" Dia.		
Well No	lb Loaded	Final Open Flow	Well No	lb Loaded	Final Open Flow	Well No	lbs Loaded	Final Open Flow
McClean A$2	6,000	146	McClean A24	12,000	201	McClean A26	37,500	237
McClean A44	6,000	40.6	McClean A25	12,000	192			
McClean A52	5,900	73	McClean A31	12,000	107			
			McClean A45	12,000	89			
			Putnam B-15	12,000	91			
Mean		86.5			136			297
Std. Dev.		54.0			55.8			

Appendix A

PHILIP R. BERGER & ASSOCIATES

REPORT

TO

E. I. DU PONT DE NEMOURS & COMPANY, INC.
Potomac River Development Lab
Martinsburg, WV 25401

OATE

September 8,. 1980

SUBJECT

VIBRATION STUDY: A Gas Stimulation Blast
in Putnam County, West Virginia
Tuesday, June 17, 1980

COPY NUMBER TWO

VIBRATION STUDY

A Gas Stimulation Blast in Putnam County, West Virginia
Tuesday, June 17, 1980

PURPOSE

The purpose of this study was to measure the ground vibration levels produced by a gas stimulation blast at Well No. A-31 in Putnam County, West Virginia, in order to compare the recorded motion to currently accepted ground vibration criteria.

THE BLAST

The blast recorded in this study was detonated at 11:58 P. M.. Tuesday, June 17, 1980. It was located in Well No. A-31 (McLean Lease). Pertinent data on the loading and firing of the shot are tabulated below.

Hole Diameter (in.)	6¼
Depth to bottom of well (ft.)	4,503
Explosives Weight (lbs.)	
EL 836	12,000
Charge Column Height (ft.)	641
Detonator	Sure Fire Electric Bomb
Stemming (ft.)	450
Type	Ohio River Gravel

The blast was loaded and fired under the supervision of Dr. Frank A. Loving, with the assistance of Mr. Walter J. Simmons.

RECORDING LOCATION

The vibrations produced by the blast were recorded with a SAFEGUARD SEISMIC UNIT IV, a seismic-triggered, velocity-recording seismograph. The instrument was set up on the ground 100 feet horizontally west of Well No. A-31 and 3,865 feet from the top of the charge column.

Recording procedures were conducted by Mr. James A. Gould.

THE SEISMOGRAPH

The SAFEGUARD SEISMIC UNIT IV is an automatically triggered instrument which produces a 4-channel tape recording of the ground and airborne vibrations produced by blasting operations. Processing of the tape with auxiliary equipment provides a film recording of the seismic and acoustic data for analysis purposes.

The film contains four (4) lines or traces, three of which record ground motion. One trace represents the horizontal component of ground motion along the line between the blast and the seismograph, and is marked "longitudinal". A second trace, marked "transverse", represents the horizontal component of motion at right angles to the above, and a third trace records vertical movement. All ground motion is resolved into these three components, with the trace movement being proportional to the rate of ground motion (particle velocity) at the recording location. For the record made in this survey, a particle velocity of 1.0 inch per second is represented by trace displacement of approximately 0.4 inch.

"Air Blast" is measured on a fourth trace when required. This measurement was not applicable in this study.

The continuous series of short vertical lines along the bottom of the record represents a time scale. These lines are recorded each 0.1 second. This scale is used for frequency computations when required.

The seismographic record.obtained in this study is enclosed at the end of this report.

RESULTS

The measurements from the blast of June 17, 1980 are given below.

Component	Maximum Particle Velocity	Predominant Frequency
Transverse	0.05 inch per second	32 Hz
Vertical	0.05 inch per second	
Longitudinal	0.03 inch per second	

DISCUSSION OF RESULTS

Over the past 40 to 50 years, research in blasting seismology has produced standards which define the vibration intensities directly related to the occurrence of structural damage. These investigations have been conducted by governmental agencies such as the United States Bureau of Mines and the National Research Council of Canada, by insurance companies, and by individual seismological consultants. One widely accepted limit, a particle velocity of 2.0 inches per second, was proposed in U. S. Bureau of Mines Bulletin No. 656, Blasting Vibrations and Their Effects on Structures, published in 1971. This limit has since been established as the legal limit in several states and is the present federal limit for vibrations at or near homes produced by blasts in connection with surface coal mining operations.

In the fall of 1979, Dr. David Siskind of the United States Bureau of Mines delivered a report to the Annual Meeting of the Eastern Section, Seismological Society of America. It covered the more recent investigations of the Bureau, made after the 1971 report, and presented some of the findings. All of the findings and recommendations are to be published within the near future in a Bureau of Mines Report "Safe Ground Vibration and Airblast Criteria" by David E. Siskind, Mark S. Stagg, and Virgil J. Stachura.

The Bureau's findings and subsequent recommendations can be summarized as follows:

1. Damage can occur at low levels of ground vibration, although with a low probability of occurrence.

2. Damage is correlated with structural response and the vibration parameters of peak particle velocity and predominant frequency of the ground motion. Vibration measurement on the ground at or close to building foundations is still advised.

3. for the prevention of threshold damage in an "old" residential structure where the predominant frequency of the ground motion is less than 40 Hz, the peak particle velocity should not exceed 0.50 inch per second in any one of the three mutually perpendicular directions, longitudinal, transverse, and vertical.

4. For the prevention of threshold damage in "new" residential structures where the predominant frequency of the ground motion is less than 40 Hz, the peak particle velocity should not exceed 0.75 inch per second in any one plane.

5. For the prevention of damage to any residential structure where the predominant frequency of the ground motion is 40 Hz or more, a peak particle velocity of 2.0 inches per second in any plane should not be exceeded.

In view of the foregoing, we recommend that where the predominant frequency of the ground motion is below 40 Hz, as was the case in this.study, a limit of .50 inch per second be considered. The maximum velocity recorded on June 17, 1980 was 0.05 inch per second. This represents ten percent (10%) of our recommended limit and is safe by a wide margin.

Respectfully submitted,

PHILIP R. BERGER & ASSOCIATES, INC.

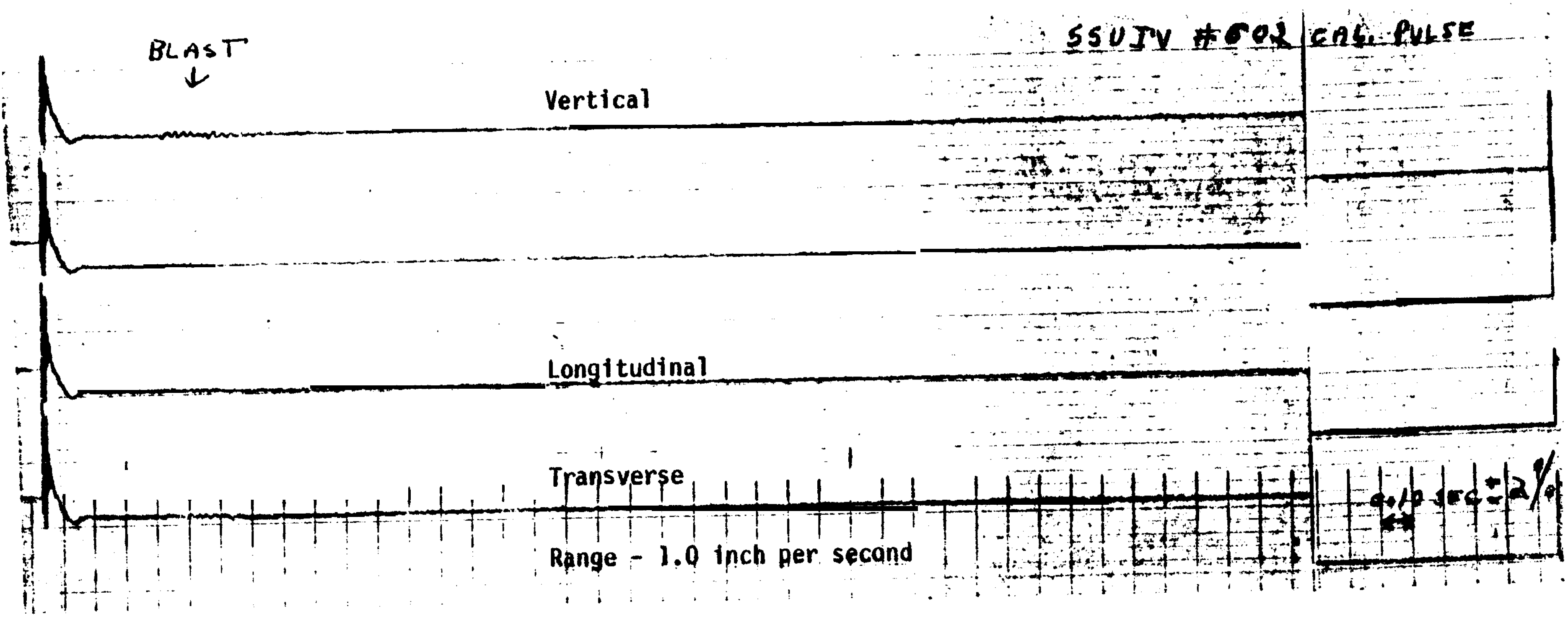
James A. Gould

James A. Gould, Vice President
Monitoring & Analysis Services

Philip R. Berger

Philip R. Berger, CPGS
President

JAG/eb



E. I. DU PONT DE NEMOURS & COMPANY, INC. - GAS STIMULATION BLAST, PUTNAM COUNTY, WEST VIRGINIA

Blast in Well No. A-31, 6/17/80, 11:58 PM - Recorded 100 feet horizontally west of the well

Appendix B

PHILIP R. BERGER & ASSOCIATES

REPORT

TO

E. I. DU PONT DE NEMOURS & COMPANY, INC.
Potomac River Dwelopment Lab
Martinsburg, WV 25401

DATE

September 8, 1980

SUBJECT

VIBRATION STUDY: A Gas Stimulation Blast at
Well No. A-26 in Putnam County, West Virginia
Saturday, August 9, 1980

COPY NUMBER ONE

VIBRATION STUDY

A Gas Stimulation Blast at Well No. A-26 in Putnam County, West Virginia
"Saturday, August 9, 1980

PURPOSE

The purpose of this study was to measure the ground vibration levels produced by a gas stimulation blast at Well No. A-26 in Putnam County, West Virginia, in order to compare the recorded motion to currently accepted ground vibration criteria.

THE BLAST

The blast recorded in this study was detonated at 4:56 P. M., Saturday, August 9, 1980. It was located in Well No. A-26 (McLean Lease). Pertinent data on the loading and firing of the shot are tabulated below.

Hole Diameter (in.)	12
Depth to bottom of well (ft.)	4,435
Explosives Weight (lbs.)	
EL 836	37,500
Charge Column Height (ft.)	505
Detonator	Sure Fire Electric Bomb
Stemming (ft.)	600
Type	Ohio River Gravel

The blast was loaded and fired under the supervision of Dr. Frank A. Loving, with the assistance of Mr. Walter J. Simmons.

RECORDING LOCATION

The vibrations produced by the blast were recorded with a SAFEGUARD SEISMIC UNIT IV, a seismic-triggered, velocity-recording seismograph. The instrument was set up on the ground 192 feet horizontally northeast of Well No. A-26 and 3,935 feet from the top of the charge column.

Recording procedures were conducted by Mr. Michael A. Dayton.

THE SEISMOGRAPH

The SAFEGUARD SEISMIC UNIT IV is an automatically triggered instrument which produces a 4-channel tape recording of the ground and airborne vibrations produced by blasting operations. Processing of the tape with auxiliary equipment provides a film recording of the seismic and acoustic data for analysis purposes.

The film contains four (4) lines or traces, three of which record ground motion. One trace represents the horizontal component of ground motion along the line between the blast and the seismograph, and is marked "longitudinal". A second trace, marked "transverse", represents the horizontal component of motion at right angles to the above, and a third trace records vertical movement. All ground motion is resolved into these three components, with the trace movement being proportional to the rate of ground motion (particle velocity) at the recording location. For the record made in this survey, a particle velocity of 1.0 inch per second is represented by trace displacement of approximately 0.4 inch.

"Air Blast" is measured on a fourth trace when required. This measurement was not applicable to this study.

The continuous series of short vertical lines along the bottom of the record represents a time scale. These lines are recorded each 0.1 second. This scale is used for frequency computations when required.

The seismographic record obtained in this study is enclosed at the end of this report.

RESULTS

The measurements from the blast of August 9, 1980 are given below.

Component	Maximum Particle Velocity	Predominant Frequency
Transverse	0.05 inch per second	40 Hz
Vertical	0.28 inch per second	
Longitudinal	0.05 inch per second	

DISCUSSION OF RESULTS

Over the past 40 to 50 years, research in blasting seismology has produced standards which define the vibration intensities directly related to the occurrence of structural damage. These investigations have been conducted by governmental agencies such as the United States Bureau of Mines and the National Research Council of Canada, by insurance companies, and by individual seismological consultants. One widely accepted limit, a particle velocity of 2.0 inches per second, was proposed in U. S. Bureau of Mines Bulletin No. 656, Blasting Vibrations and Their Effects on Structures, published in 1971. This limit has since been established'as'the legal limit in several states and is the present federal limit for vibrations at or near homes produced by biasts in connection wi'th surface coal mining operations.

Research by the U. S. Bureau of Mines since 1971 has served to reaffirm the validity of the limit of 2.0 inches per second for vibration with frequencies above 40 hertz, the frequency recorded in this study. At the 1979 meeting of the Eastern Section, Seismological Society of America, and at a subsequent meeting in Canada, the Bureau's Dr. David Siskind stated that, for frequencies above 40 hertz, a particle velocity limit of 2.0 inches per second should be adhered to in order to prevent threshold damage within residential structures. Threshold damage is defined as "the onset of cosmetic damage; small plaster cracks at joints between construction elements; lengthening of old cracks."

The maximum velocity recorded from the blast of August 9th was 0.28 inch per second. This represents fourteen percent (14%) of a limit of 2.0 inches per second, and is safe by a wide margin.

Respectfully submitted,

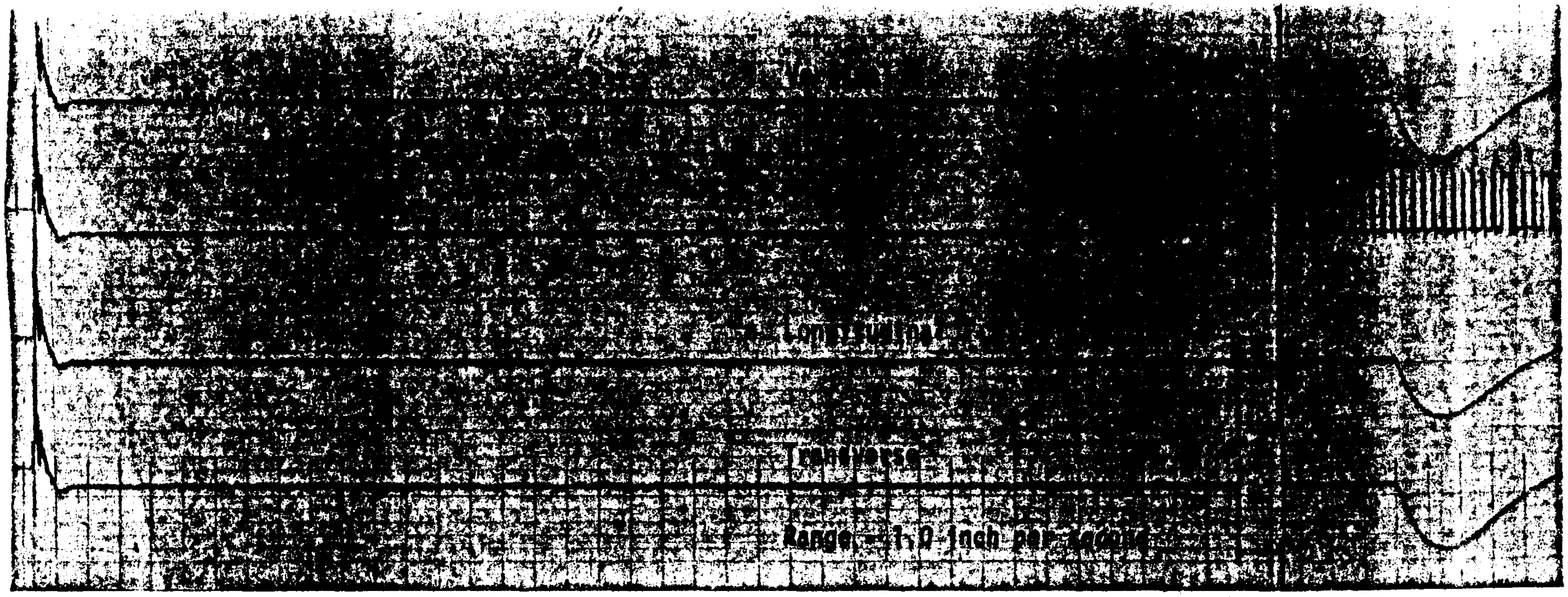
PHILIP R. BERGER & ASSOCIATES, INC.

Michael A. Dayton

Michael A. Dayton
Technical Representative

Philip R. Berger, CPGS
President

MAD/eb



E. I. DU PONT DE NEMOURS & COMPANY, INC. - GAS STIMULATION BLAST, PUTNAM COUNTY, WEST VIRGINIA

Blast in Well No. A-26, 8/9/80, 4:56 PM - Recorded 192 feet horizontally northeast of the well.

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